EXECUTIVE SUMMARY

AN ICE JAM FLOOD STUDY
FOR
PERTH-ANDOVER and the BEECHWOOD HEADPOND

PHASE II

PREPARED FOR

NEW BRUNSWICK DEPARTMENT OF
MUNICIPAL AFFAIRS AND ENVIRONMENT

PREPARED BY

SUB SURFACE SURVEYS
F1784 / F1856

FEBRUARY, 1989

1. INTRODUCTION

In late March and the first week of April, 1987, the Saint John River between the Beechwood Dam and the Aroostook River, and in particular the Village of Perth-Andover, New Brunswick experienced serious flooding as a result of an ice jam. Many Village residents and patients at the hospital were evacuated. The railway bridge was destroyed, and many homes and businesses were damaged, some beyond repair.

In the Village of Perth-Andover approximately 170 properties were affected by the 1987 flood; almost 70 of these suffered varying degrees of structural damage. The damage resulting from the flooding was caused by overland flooding and through-ground flow caused by the flood related hydraulic gradient and from bank erosion by flood waters and related instability.

As a result of serious ice-related events on the Saint John River, in particular the 1987 ice jam flood at Perth-Andover and the previous ice jam flood at Simonds in 1986, a Working Group and a Review Committee were appointed to undertake a thorough study of the flooding problem. The Working Group and Review Committee were given the mandate to make recommendations for action that could be taken to reduce the risk of flooding and subsequent related damages.

These committees developed a phased program, beginning with a study (Phase I) to collect and review existing information relevant to the flooding problem in the area. The first study also included an evaluation of the requirements for field investigations and the carrying out of those investigations. This study was completed in June, 1988 by Gemtec.

Objectives

Sub Surface Surveys was commissioned to conduct the present study as Phase II of the study program. The objectives of this study are to identify various feasible structural and non-structural flood damage reduction measures, and to estimate the costs and where possible, the benefits of each. The details of the requirements of this study are outlined in the Terms of Reference dated June 1988.

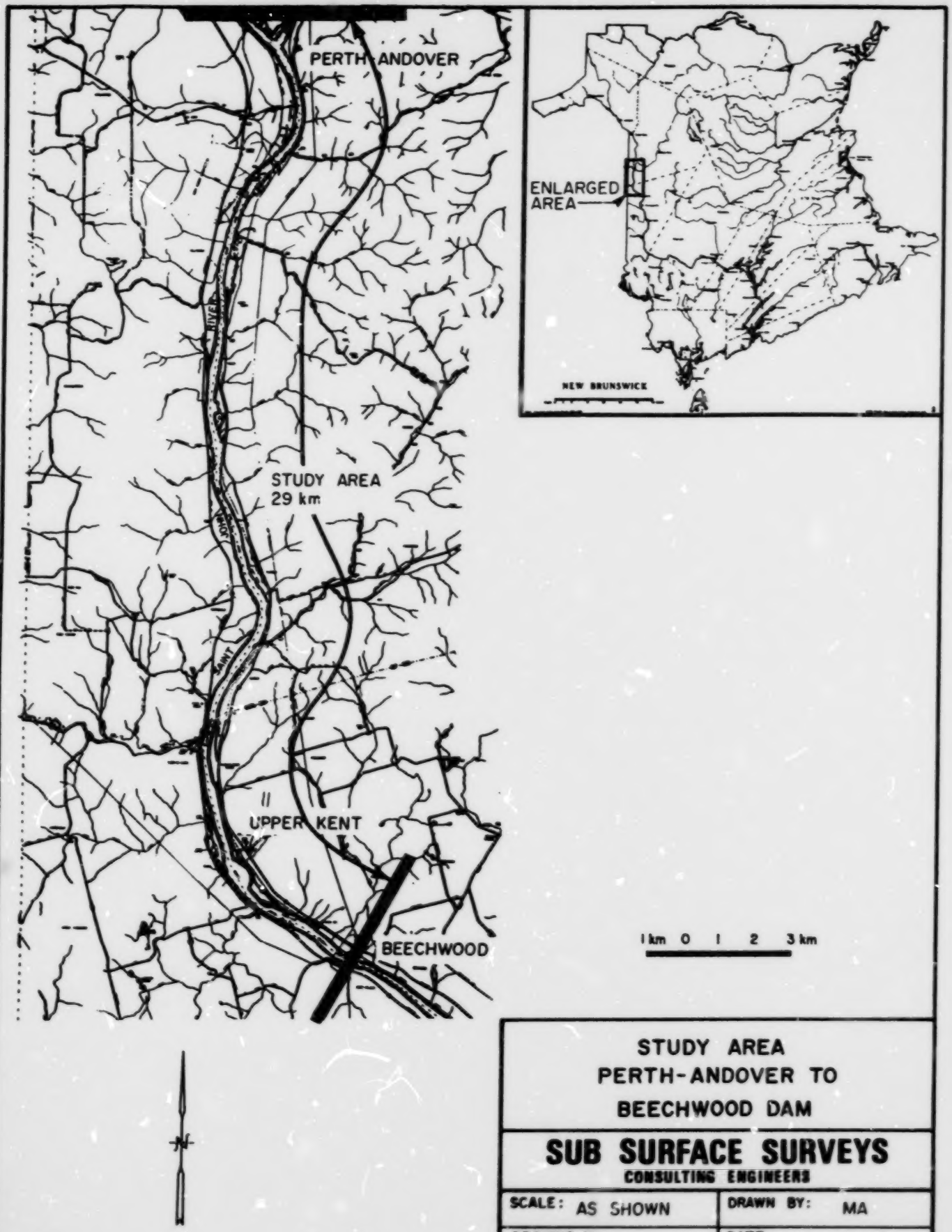
Study Area

The Study Area (Map 1) is located in a reach of the Saint John River between the Beechwood Dam and the junction of the Aroostook River. The primary focus of the study is the Village of Perth-Andover which experienced the most extensive and dramatic flood damage. The secondary focus is the area outside the Village, along the banks of the Saint John River, from the location of the 1987 ice jam near Upper Kent to the upstream extent of the effect of the ice jam, which was near the mouth of the Aroostook River. This area covers most of the area which is called the Beechwood Headpond.

Authorization

Sub Surface Surveys has undertaken this study for the New Brunswick Department of Municipal Affairs and Environment. The study has been completed in consultation with the Working Group, which was comprised of representatives from the Department of Municipal Affairs and Environment, the New Brunswick Department of Transportation, the New Brunswick Department of Agriculture, and the New Brunswick Electric Power Commission.

The Village of Perth-Andover was historically two communities, Perth on the eastern bank and Andover on the west.



STUDY AREA
PERTH-ANDOVER TO
BEECHWOOD DAM

SUB SURFACE SURVEYS
CONSULTING ENGINEERS

SCALE: AS SHOWN	DRAWN BY: MA
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2. METHODOLOGY

This study involved a multi-disciplinary approach with each discipline being interrelated with the overall analysis of the ice jam flood study. The specific tasks in the various disciplines are summarized below.

In addition to this Executive Summary, a Summary Document and a comprehensive Technical Background Report have been prepared. These were submitted under separate cover to the Working Group contain all supporting data and analyses pertinent to the findings of the study.

Planning

To develop appropriate flood protection measures, a comprehensive inventory of land use and structures within the Study Area was compiled. Based on this inventory, the existing zoning, current regulations (municipal plan), land use control measures and damage potential from flooding were reviewed. These were ranked by flood damage potential to provide an effective method for evaluating protection required for an individual structure or groups of structures.

Hydrotechnical

The hydrotechnical analysis considered the various drainage systems within the area and how they respond to rapid increases in the River level. The objective of these investigations was to evaluate the effectiveness of the use of flap gates on the culverts emptying into the Saint John River. The frequency of ice jam flooding in the Study Area was also addressed with the objective of assigning a frequency of recurrence to the 1987 flood event.

Geotechnical

The nature of bank erosion and stability was reviewed as it pertains to both normal and elevated river flows. The permeability of the subsurface in the Study Area was determined by field trials in order to evaluate the impact of through-ground flow. Criteria were developed which can be used to measure the extent of protection required.

Engineering

A range of possible flood control measures were compiled and evaluated. Preliminary conceptual designs were prepared specific to the Study Area. The costs of the various design options were determined and the most suitable of these were subjected to an economic analysis.

Economics

A benefit-cost analysis was conducted to evaluate the selected alternatives in terms of cost and the degree of flood protection provided. The analysis considered the impact of flood protection on both the private and public sectors, and evaluated the relative benefits to each.

3. CONCLUSIONS AND RECOMMENDATIONS

The Technical Background Report details the methodology used in defining the aspects of the flooding and associated remedial measures that would be appropriate for the Village of Perth-Andover and the Beechwood Headpond area.

The Summary Document presents the synopsis of the findings of the Technical Background Report. It is suggested that the complete documentation be reviewed as additional actions and supporting

data are included that may be significant.

PLANNING

1) It is recommended that flood zones be established and controlled by enactment of a By-Law for the Village of Perth-Andover.

2) Incentives should be considered for the existing residents to assist them in either floodproofing or relocating.

3) Development should be discouraged within the defined flood zones.

4) Official disclosure of the flood risk should be made to notify potential developers within the flood risk area.

5) Similar enforcement of development in the unincorporated areas could be undertaken.

HYDROTECHNICAL

6) Culverts have sufficient capacity under backflow conditions to contribute significantly to flooding.

7) It is concluded that culverts should be blocked by flap gates, to protect against the inward flow during flooding.

GEOTECHNICAL

8) It was concluded that the flood water movement in the Village by through-ground flow was a significant factor in the flooding.

9) It is recommended that a study should be undertaken to define the response of the groundwater table to the rise in the River water level.

10) Thirty-eight (38) sites of riverbank erosion were identified and it was concluded that five (5) sites are in need of immediate action.

11) Remedial measures recommended for slope stabilization are presented in the Summary Document.

REMEDIAL MEASURES

12) Further study of the ice management capabilities of the proposed Morrell Hydroelectric Development should be undertaken. The development should be encouraged as a potential long term solution to the problem of ice jam flooding at Perth-Andover.

13) A number of potential remedial measures for flood protection were reviewed from which ten (10) selected measures are recommended and were analyzed in detail.

14) It is recommended that the hospital be protected from overland and through-ground flows. This protection is recommended regardless of other remedial actions selected.

ECONOMICS

15) The selected remedial measures are presented in Table 1 with the associated costs and the ranking based on the benefit-cost ratios developed.

Table 1

Cost Estimates and Benefit-Cost Ratios for Remedial Measures

Remedial Measure	Remedial measures Cost	Benefit-Cost Ratio
5) Raise Roads	$8,000,000	2.12
2) Concrete Floodwall	$8,120,000	2.09
7) Elevate structures affected by overland flow	$6,980,000	2.05
6) Raise Roads and raise structures	$8,740,000	1.94
8) Elevate to max. of 1 m, relocate others	$8,060,000	1.77
3) Sheetpile Floodwall	$10,290,000	1.65
9) Elevate commercial, relocate residents	$9,410,000	1.52
10) Relocate structures affected by overland flow	$11,160,000	1.52
1) Earth Dike	$16,860,000	1.00
4) Sheetpile Floodwall to cutoff	$18,570,000	0.91

Note: * Cost estimates for remedial measures include protection of hospital.
* Remedial measures listed by decreasing benefit cost ratio.
* Interest rate = 10%, base flood of 100 year return assumed.

16) It is concluded that:

- Maximizing the dollar value of benefits per dollar spent leads to the selection of the remedial measure of raising roads, as does maximizing the net present value of the remedial project.

- An examination of the additional benefits due to an additional cost increment leads to the selection of the remedial measure of raising the roads.

- If raising the roads is excluded on the grounds it carries negative externalities, the most efficient remedial measure becomes the concrete floodwall.

- The ranking of measures is insensitive to the choices of the discount rate and the flood return period.

- The construction of the remedial measure will have positive effects on employment and incomes in the Province.

17) Non-economic issues such as aesthetics, social, cultural and planning considerations may alter the ranking of the remedial measures which have been assessed from solely an economic perspective.

91-03086/

RESUME ADMINISTRATIF

ETUDE SUR LES INONDATIONS CAUSEES PAR LES EMBACLES

POUR

PERTH-ANDOVER ET LE RESERVOIR DE BEECHWOOD

PHASE II

PREPARE POUR

LE MINISTERE DES AFFAIRES MUNICIPALES

ET DE L'ENVIRONNEMENT

PAR

SUB SURFACE SURVEYS

F1784 / F1856

FEVRIER 1989

(Translated from English by McLaughlin Translation Company Ltd.)

1. INTRODUCTION

A la fin du mois de mars et durant la première semaine d'avril 1987, la partie du fleuve Saint-Jean entre le barrage de Beechwood et la rivière Aroostook, et en particulier dans le village de Perth-Andover, Nouveau-Brunswick, ont subi des inondations causées par des embâcles. Bon nombre de résidents du village et de patients à l'hôpital ont été évacués. Le pont ferroviaire a été détruit, et bon nombre de maisons et de commerces ont été endommagés, certains n'étant même plus réparables.

Dans le village de Perth-Andover, environ 170 propriétés ont été affectées par l'inondation de 1987; près de 70 de ces propriétés ont subi des dommages structurels à divers degrés. Les dommages ont été causés par l'inondation des terres et l'écoulement souterrain provoqué par le gradient hydraulique relié à l'inondation et par l'érosion de la rive provoquée par les eaux de l'inondation et l'instabilité connexe.

A la suite de ces événements causés par la glace sur le fleuve Saint-Jean, en particulier l'inondation à Perth-Andover en 1987 et l'inondation à Simonds en 1986 causées par les embâcles, un groupe de travail et un comité de révision ont été nommés pour entreprendre une étude approfondie du problème des inondations. Ce groupe de travail et le comité de révision ont reçu le mandat de recommander des mesures qui pourraient être prises pour réduire les risques d'inondation et les dommages connexes subséquents.

Ces comités ont élaboré un plan d'étude à plusieurs phases, commençant par une étude (phase I) en vue de recueillir et d'étudier les données pertinentes actuelles relatives aux problèmes des inondations dans la région. La première étude comportait une évaluation des critères des études sur place ainsi

que l'étude proprement dite. Cette étude a été achevée en juin 1988 par Gemtec.

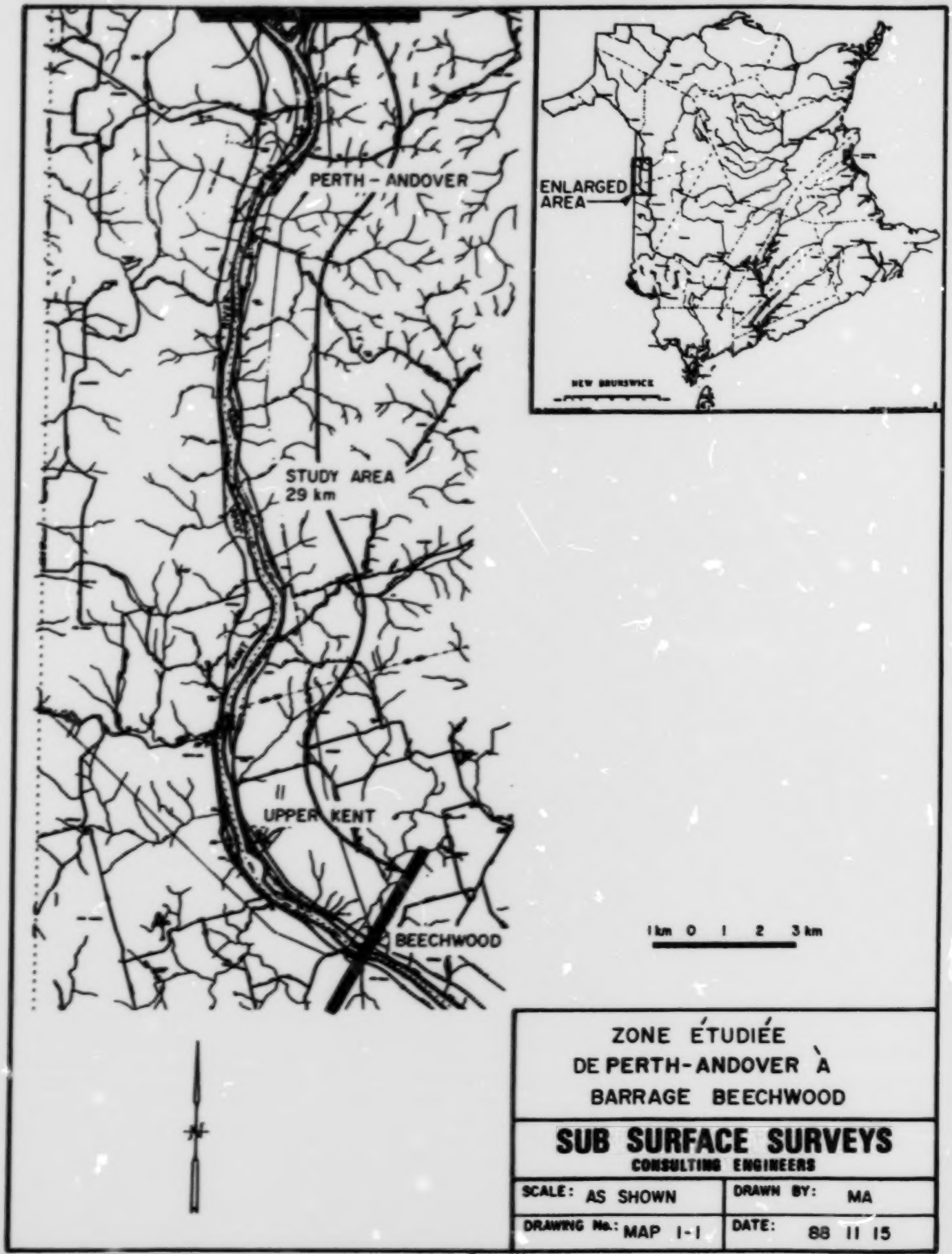
Objectifs

On a retenu les services de Sub Surface Surveys pour effectuer l'étude actuelle qui constitue la deuxième phase du plan d'étude. Les objectifs de cette étude sont d'identifier les diverses mesures structurales et non structurales de réduction des dommages causés par les inondations, d'établir les coûts approximatifs, et dans la mesure du possible, les bienfaits de chaque mesure. Les critères détaillés de cette étude sont expliqués dans les attributions datées de juin 1988.

Zone étudiée

La zone visée par l'étude (carte 1) est située sur une étendue du fleuve Saint-Jean entre le barrage de Beechwood et la jonction de la rivière Aroostook. L'étude vise principalement le village de Perth-Andover qui a subi les dommages les plus importants causés par les inondations. L'étude vise ensuite la région à l'extérieur du village, le long des rives du fleuve Saint-Jean, à partir du lieu des embâcles de 1987 près de Upper Kent jusqu'à la portée en amont de l'effet de l'embâcle, qui se trouvait près de l'embouchure de la rivière Aroostook. Cette zone couvre la majeure partie de la région désignée sous le nom du lac artificiel de Beechwood.

Le village de Perth-Andover a toujours englobé deux localités, Perth sur la rive est et Andover sur la rive ouest.



ZONE ÉTUDIÉE
DE PERTH-ANDOVER À
BARRAGE BEECHWOOD

SUB SURFACE SURVEYS
CONSULTING ENGINEERS

SCALE: AS SHOWN	DRAWN BY: MA
DRAWING No.: MAP 1-1	DATE: 88 11 15

Autorisation

Sub Surface Surveys a entrepris cette étude pour le ministère des Affaires municipales et de l'Environnement. L'étude a été effectuée en consultation avec le groupe de travail qui se composait de représentants du ministère des Affaires municipales et de l'Environnement, du ministère des Transports du Nouveau-Brunswick, du ministère de l'Agriculture du Nouveau-Brunswick et de la Commission d'Énergie électrique du Nouveau-Brunswick.

2. MÉTHODOLOGIE

Cette étude a mis un accent multidisciplinaire sur les différents aspects, chaque discipline étant interreliée à l'analyse globale de l'étude des inondations causées par les embâcles. Les tâches précises sont résumées ci-dessous.

Outre ce Résumé administratif, un Document sommaire et un Rapport technique général exhaustif ont été préparés. Ces documents, qui ont été soumis sous pli séparé au groupe d'étude, contiennent toutes les données d'appui et analyses pertinentes par rapport aux conclusions de l'étude.

Planification

Pour élaborer des mesures adéquates de protection contre les inondations, un inventaire exhaustif de l'utilisation des terrains et des structures dans la zone étudiée a été compilée. Selon cet inventaire, le zonage de développement actuel, les règlements actuels (plan municipal), les mesures de contrôle et l'utilisation des terres et les dommages éventuels pouvant résulter de l'inondation ont été examinés. Ces aspects ont été classés en fonction des risques de dommages provoqués par les

inondations afin d'évaluer efficacement le degré de protection exigé pour les structures individuelles ou les groupes de structures.

Hydrotechnique

L'analyse hydrotechnique a examiné les divers systèmes de drainage dans la région et la façon dont ils réagissent à la montée rapide du niveau du fleuve. Ces enquêtes avaient pour but d'évaluer l'efficacité de l'utilisation des vannes à charnière et des ponceaux se déversant dans le fleuve Saint-Jean. La fréquence des inondations causées par les embâcles dans la zone étudiée a été examinée en vue d'établir une intervalle de récurrence par rapport à l'inondation de 1987.

Géotechnique

La nature de l'érosion de la rive et la stabilité ont été examinées puisqu'elles sont reliées aux écoulements élevés et normaux du fleuve. La perméabilité de la sous-surface dans la zone étudiée a été évaluée par des essais sur place afin d'évaluer l'impact de l'écoulement souterrain. Des critères ont été établis afin de mesurer le degré de protection exigé.

Ingénierie

Différentes mesures possibles de contrôle des inondations ont été compilées et évaluées. Des plans conceptuels préliminaires ont été préparés pour la zone étudiée. Le coût des diverses options en matière de conception a été déterminé et les options les plus convenables ont été soumises à une analyse économique.

Faisabilité

Une analyse avantages-coût a été effectuée pour évaluer les solutions choisies par rapport au coût et au degré de protection assuré contre les inondations. L'analyse a examiné l'impact de la protection contre les inondations sur les secteurs public et privé, et évalué les avantages relatifs de chacun.

3. CONCLUSIONS ET RECOMMANDATIONS

Le Rapport technique général décrit en détail la méthode utilisée pour définir les aspects des inondations et les mesures de redressement pertinentes qui conviendraient pour le village de Perth-Andover et la zone du réservoir de Beechwood.

Le Document sommaire présente un résumé des constatations contenues dans le Rapport technique général. On propose que toute la documentation soit étudiée puisque d'autres mesures et données à l'appui qui pourraient être pertinentes sont présentées.

PLANIFICATION

1) Il est recommandé que les zones inondables soient établies et contrôlées par l'adoption d'un arrêté pour le village de Perth-Andover.

2) Il faudrait envisager des mesures d'encouragement pour aider les résidents à se protéger contre les inondations ou à se reloger.

3) Il faudrait décourager les aménagements dans les zones inondables définies.

4) Le risque d'inondation devrait être divulgué officiellement pour aviser les promoteurs éventuels dans la zone qui pourrait être inondée.

5) Les mêmes mesures d'aménagement devraient être entreprises dans les zones non constituées en municipalité.

HYDROTECHNIQUE

6) Les ponceaux ont suffisamment de capacité en cas de contre-courant pour contribuer de façon significative aux inondations.

7) On conclut que les ponceaux devraient être bloqués par des vannes à charnière pour assurer une protection contre l'écoulement interne pendant les inondations.

GÉOTECHNIQUE

8) Il a été conclu que le mouvement de l'eau des inondations dans le village par les écoulements souterrains pourrait être un facteur déterminant des inondations.

9) Il est recommandé qu'une étude soit entreprise pour définir la réaction de la nappe d'eau souterraine par rapport à la montée du niveau d'eau du fleuve.

10) Trente-huit (38) lieux d'érosion de la rive du fleuve ont été identifiés et il a été conclu que cinq (5) de ces lieux justifient la prise de mesures immédiates.

11) Les mesures de redressement recommandées pour la stabilisation des pentes sont présentées dans le Document sommaire.

MESURES DE REDRESSEMENT

12) D'autres études de la capacité de l'aménagement hydroélectrique Morrell proposé de contrôler les glaces devraient être entreprises. Cet aménagement devrait être encouragé à titre de solution éventuelle à long terme au problème des inondations causées par les embâcles à Perth-Andover.

13) Un certain nombre de mesures de redressement potentielles pour la protection contre les inondations ont été examinées, dont dix (10) ont été choisies, recommandées et analysées en détail.

14) Il est recommandé que l'hôpital soit protégé contre les écoulements de surface et les écoulements souterrains. Cette protection est recommandée sans égard aux autres mesures de redressement choisies.

FAISABILITÉ

15) Les mesures de redressement choisies sont présentées au tableau 1, ainsi que les coûts connexes et elles sont classées selon les rapports avantages-coût établis.

16) Il est conclu que :

- La maximisation de la valeur monétaire des avantages par dollar dépensé mène à la sélection du soulèvement des chemins comme mesure de redressement, comme c'est

aussi le cas pour la maximisation de la valeur actuelle nette du projet de redressement.

- Un examen des autres avantages provenant de l'augmentation des autres coûts mène à la sélection des mesures correctrices telles que le soulèvement des chemins.

- Si le soulèvement des chemins est exclu parce qu'il comporte des effets négatifs, la mesure la plus efficace contre les inondations devient la construction d'un mur en béton.

Tableau 1

Estimation des coûts et rapport avantages-coût pour les mesures de redressement

Mesure de redressement		Mesures de redressement Coût	Rapport Avant.-coût
5)	Soulèvement des chemins	8 000 000 $	2,12
2)	Mur en béton	8 120 000 $	2,09
7)	Élévation des structures affectées par les écoulements de surface écoulements de surface	6 980 000 $	2,05
6)	Élévation des chemins et des structures	8 740 000 $	1,94
8)	Élévation a 1 m max., relogement des autres	8 060 000 $	1,77
3)	Palplanche	10 290 000 $	1,65
9)	Élévation des propriétés commerciales, relogement des résidents	9 410 000 $	1,52
10)	Relogement des structures affectées par les écoulements de surface	11 160 000 $	1,52
1)	Digue de terre	16 860 000 $	1,00
4)	Palplanche pour couper l'écoulement souterrain	18 570 000 $	0,91

Note : • Les prévisions des coûts pour les mesures de redressement comprennent la protection de l'hôpital.
• Mesures de redressement énumérées en fonction du rapport décroissant avantages-coût.
• Taux d'intérêt = 10 %, base d'inondation supposant une période de récurrence de 100 ans.

- Le classement des mesures ne tient compte ni des choix du taux d'escompte, ni de la période de récurrence des inondations.

- La mise en oeuvre d'une mesure de redressement aura des effets positifs sur l'emploi et les revenus dans la province.

17) Les questions non économiques telles que l'esthétique, les aspects sociaux, culturels et la planification peuvent modifier le classement des mesures de redressement qui ont été évaluées à partir d'une perspective économique seulement.

SUMMARY DOCUMENT
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PHASE II

PREPARED FOR

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FEBRUARY 1989

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1.0 INTRODUCTION

In late March and the first week of April, 1987, the Saint John River between the Beechwood Dam and the Aroostook River, and in particular the Village of Perth-Andover, New Brunswick experienced serious flooding as a result of an ice jam. Many Village residents and patients at the hospital were evacuated. The railway bridge was destroyed, and many homes and businesses were damaged, some beyond repair.

In the Village of Perth-Andover approximately 170 properties were affected by the 1987 flood; almost 70 of these suffered varying degrees of structural damage. The damage was a result of overland flooding, through-ground flow caused by the flood related hydraulic gradient and from bank erosion by flood waters and related instability.

In general there are two types of flood events; for the purposes of this study, the following definitions have been applied:

- Open water flooding is the result of high flows in a river which exceed its bankfull capacity. This causes the rising waters to extend into the floodplain; and

- Ice jam floods are the result of the sudden stoppage of ice moving on a river during breakup. The stoppage causes a temporary dam with a rapid rise in water level behind it. The water levels associated with an ice jam flood are usually much higher than would occur during an open water flood.

As a result of serious ice-related events on the Saint John River, in particular the 1987 ice jam flood at Perth-Andover and the previous 1986 ice jam flood at Simonds, a Working Group and a

Review Committee were appointed to undertake a thorough study of the flooding problem. The Working Group and Review Committee were given the mandate to make recommendations for action which could be taken to reduce the risk of flooding and subsequent related damages.

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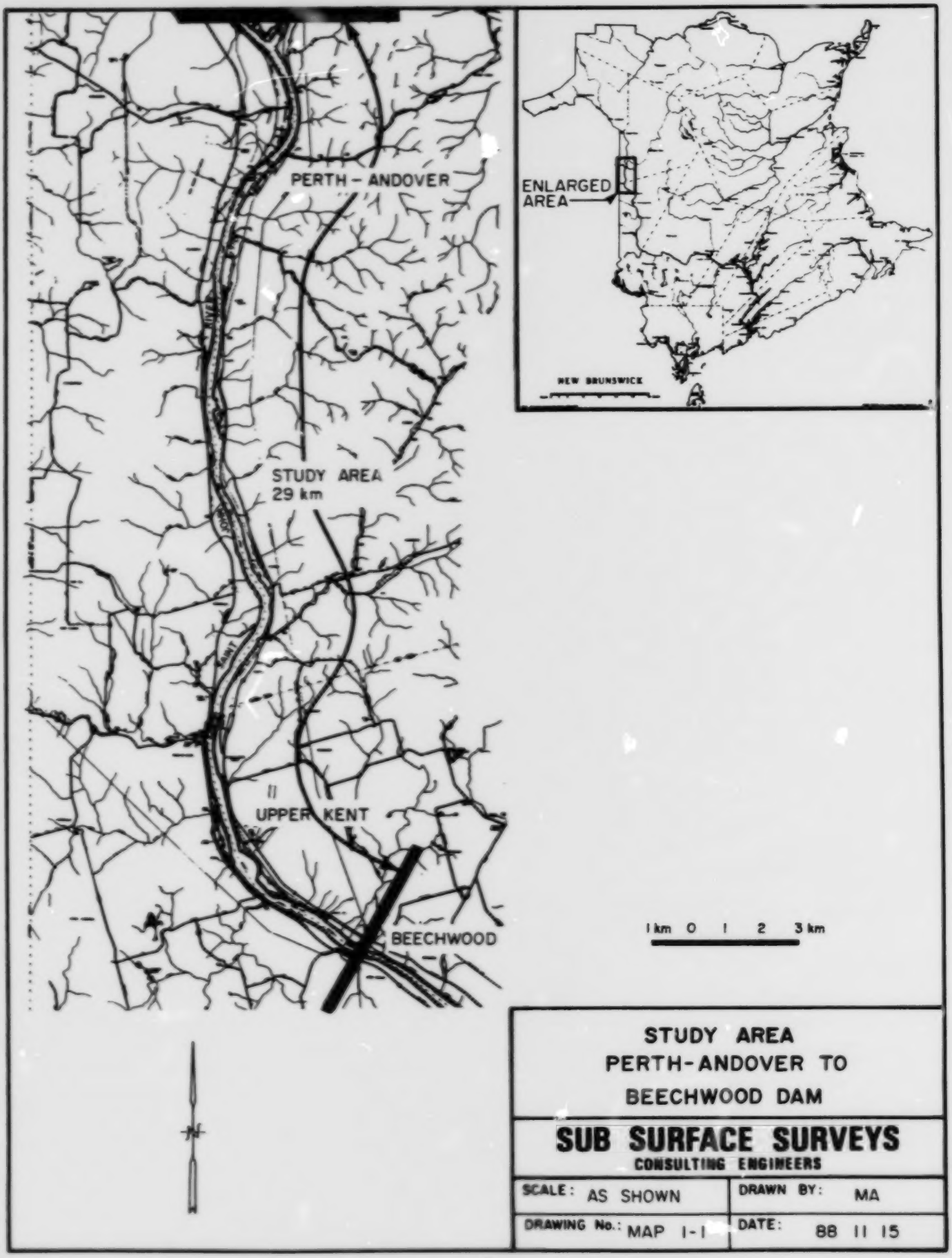
In addition to this Summary Document, a comprehensive Technical Background Report has been prepared. This Report was submitted under separate cover to the Working Group, and contains all supporting data and analyses pertinent to the findings of the Study.

1.2 Study Area

The Study Area (Map 1-1) is located in a reach of the Saint John River between the Beechwood Dam and the mouth of the Aroostook River. The primary focus of the study is the Village of Perth-



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PERTH-ANDOVER TO
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The Village of Perth-Andover was historically two communities, Perth on the eastern bank and Andover on the west.

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2.0 BACKGROUND INFORMATION

The Saint John River has been subject to extensive flooding along its length. Flooding has been very serious, warranting the establishment of the Saint John River Forecast Centre in 1973, which provides a warning of high water levels and flooding events. The Centre provides estimates of open water levels on a daily basis during flood conditions but does not attempt to forecast the occurrence of ice jams or ice jam related flood levels. The Centre does monitor ice conditions and maintains a group of observers. The start of ice breakup is monitored and warnings are issued to areas which are prone to ice jam flooding.

There are several reports on the extent and nature of flooding in the upper reaches of the Saint John River, including such major reports as **Saint John River, Analysis of 1976 Ice Jams** (Acres, 1976), **New Brunswick Flood, April-May 1973** (IWD, 1974) and **1987 Saint John River Flooding** (Acres, 1988a) and **A Comparison of the 1976 and 1987 Saint John River Ice Jam Flooding with Emphasis on Antecedent Conditions** (Dublin and Humes, 1988).

2.1 Flood Events

In the period of March 29 to April 6, 1976, severe ice jamming and related flooding occurred in various locations of the Saint John River. Extensive damage occurred as a result of the flooding. The event was documented by Acres (1976) and Galbraith (1980) who provided details of the climatic, hydrologic and hydraulic conditions at the time of the event. The water level in Perth-Andover reached an elevation of 78.15 m (256.3 ft) above geodetic datum, causing inundation of a large portion of the Village.

Under the auspices of the Federal-Provincial Flood Damage Reduction Program, the Inland Waters Directorate (1979) undertook a study to determine the 1 in 20 and 1 in 100 year flood profile in the Beechwood Headpond area. This study led to the publication of a flood risk contour map showing the flood risk zones for the Village of Perth-Andover. Although the mandate of the study was to identify these zones for open water flood conditions, the maximum historic event, which was the ice jam related flood of 1976, was also depicted. This event produced a maximum water level in the Village of 78.15 m (256.3 ft), 2 m (6.6 ft) higher than the 1 in 100 year open water event. The frequency of the ice jam flood is not related to that of the open water event, and is depicted as an historical event of undetermined frequency.

In the period of late March to approximately April 5, 1987, severe ice jamming occurred in the Saint John River in the reach between Grand Falls and Beechwood (Map 1-1). The ice jam moved down the River and lodged near Upper Kent, where it caused water levels to reach a maximum of 79.6 m (261.1 ft) in Perth-Andover (Acres, 1988a). The levels in Perth-Andover were 3.5 m (11.5 ft) higher than the 1 in 100 year open water flood level and about 1.5 m (5 ft) higher than the previous maximum historic flooding level, recorded in 1976 (IWD, 1979).

There has been some minor flooding in the past from high open water levels at Perth-Andover. These were relatively minor events and generally are not perceived as serious flooding by the residents since no structures were affected. The land within the 1 in 20 year flood risk zone has very limited development; any flood below that level would not affect a significant portion of the developed property in the Village. The present study does not investigate the nature or extent of past open water flood events.

3.0 FLOODPLAIN DEVELOPMENT CONTROL

3.1 Perth-Andover

3.1.1 Land Use and Building Inventory

To develop appropriate flood protection measures, a comprehensive inventory of land use and structures within the flood area was compiled. The Study Area included riverbank areas, below the 1987 flood level, from the Beechwood Dam to Aroostook Junction (Map 1-1). The inventory was compiled by collating data from previous reports and studies and air photos. This information was then supplemented by:

- field surveys (air and highway);
- input from meetings with local residents; and
- conversations with local officials.

The land use inventory of the Village of Perth-Andover revealed the following uses:

- RESIDENTIAL: apartments, duplexes, single-detached and mobile homes;

- AGRICULTURAL: barns and storage sheds;

- INSTITUTIONAL: hospital and auxiliary structures, ambulance storage, Village Office, fire department, library, schools, Government Offices, Courthouse, churches, cemeteries, and organizational meeting halls;

- INDUSTRIAL AND COMMERCIAL: food, clothing, jewellery, drug stores, banks, restaurants, and warehouses;

- HAZARDOUS PRODUCT STORAGE: municipal sewage lagoon, fuel and natural gas establishments, warehouses storing hazardous substances, and industrial structures and processes that use hazardous substances; and

- TRANSPORTATION: highway, rural collectors, secondary roads, and railways.

The impact of potential flooding on these land include but is not necessarily limited to:

- the loss of human or animal life and/or injury;

- property damage to residential and agricultural buildings;

- personal loss of revenue or income; loss of valuable personal, corporate, and government historic records or archives;

- property damage and loss of revenue for commercial and industrial establishments;

- immediate danger (fires, explosions) and long term and long range environmental problems affecting downstream surface and groundwater quality from commercial and industrial, warehouses or storage buildings housing hazardous substances;

- the isolation of local residents and the prevention of access to facilities and essential services located outside the flooded area;

- property damage and loss of economic revenue for both the Canadian Atlantic Railway (CPR) and the economic activities dependent upon rail service; and

- property damage or loss of land to erosion by flood waters.

3.1.2 Existing Development Zoning

The Provincial Department of Municipal Affairs and Environment, enables incorporated municipalities within the province to have a Municipal Plan By-Law and a Zoning By-Law. The objectives of these By-Laws are to create a safe, orderly, and efficient plan for municipal development. The Village of Perth-Andover Municipal Plan contains policy statements which are of concern with respect to flooding in the Study Area.

A zoning By-Law is used to achieve the goals and objectives set out in the policies within a municipal plan. The zoning By-Law segregates physical space within the municipality by defining the acceptability of land use categories. A written description of each category of land use is supplemented by a zoning map depicting the location of each zone. The municipality has the power to control and prohibit the development of inappropriate land use in each zone. Present land use is illustrated in Maps 3-1 and 3-2 (at the back of the Document).

3.1.3 Current Regulations

The present Municipal Plan for the Village of Perth-Andover contains few constraints with respect to protection from flooding of the Saint John River at magnitudes comparable to the 1987 flood.

The Municipal Plan is not a static plan. It is a flexible plan which can be altered in light of changing circumstances. Under Section 18 of the Municipal Plan By-Law, the plan is required to be reviewed every five years and anytime within the five year period, amendments can be made. Plan amendments become necessary when the application of a policy or standard in this plan is not in the best interests of the community as a whole. Amendments which are made to suit individual preference and not in the best interests of the community can weaken the plan making it a less effective By-Law.

The **Community Planning Act** of the Province of New Brunswick has several sections which are relevant to the regulation of land use for the prevention of damage by flooding. Specifically under Section 41.1(1) of the **Act** where a municipality requests, the Minister of Municipal Affairs and Environment may designate any area within the municipality to be a flood risk area. Where a

flood risk area has been designated pursuant to Section 41.1(1), Section 41.2(1) empowers the Council to enact a Flood Risk Area By-Law to be effective within the flood risk area and to provide for:

(a) ensuring maintenance of an adequate floodway for conveyance of flood waters;

(b) conserving the flood-water storage capacity of such areas; and

(c) protecting new development in such areas from the risk of flood damage.

Without limiting the generality of Section 12 of the Municipal Plan By-Law, under Section 41.2(2), a Flood Risk Area By-Law may prescribe Engineering standards, designs and techniques to be followed in all development within the flood risk area and may prohibit all development except in accordance with the prescribed standards, designs and techniques.

For the protection of people located within the potential flood area within the Village of Perth-Andover, the Provincial Government and the Village of Perth-Andover should develop and strictly enforce a Flood Risk Area By-Law.

3.1.4 Land Use Control Options

It is recommended that the regulatory measures outlined below be considered to reduce damage caused by future flooding in the Village of Perth-Andover.

(1) The flood zones within the Village of Perth-Andover for the maximum historical case should be defined in addition to the 1 in 20 and the 1 in 100 year flood levels. The previous maximum historic flood level

(1976 ice jam flood) was greatly exceeded by the 1987 ice jam flood. The 1987 flood elevation of 79.6 m (261.1 ft) should be used to define the flood risk zone due to overland flooding. In addition, a further zone should be defined to determine the limit of structural damage, i.e., the 82.5 m (270.6 ft) contour.

(2) Incentives could be considered for residents within the flood risk zone to help them floodproof existing structures to conform to minimum levels of flood protection. This will eliminate or reduce future flooding compensation expenditures.

(3) Incentives could be considered for residents within the flood risk zone to assist them in relocation if this action is deemed appropriate.

(4) Development could be discouraged within the flood risk zone by making it conditional on the provision of appropriate floodproofing measures.

(5) An official disclosure of flood risk could be provided to any individual transferring, purchasing, or leasing property within the flood risk zone.

3.1.5 Municipal Responsibilities

The Village must review its Municipal Plan to incorporate any necessary amendments for the floodplain.

The Village of Perth-Andover may enforce development regulations in the floodplain through restrictive zoning only, adoption of a Flood Risk Area By-Law, or a combination of both.

Restrictions on future development and expansions within the flood area can be achieved through the use of rigorous enforcement of zoning legislation.

On the other hand the adoption of an appropriate Flood Risk Area By-Law would enable the Village to develop protective measures aimed more specifically at mitigating flood damage. It is felt that the development of an appropriate Flood Risk Area By-Law would be the most effective means of control; development in the floodplain could be specifically controlled. A proposed Flood Risk Area By-Law for the Village of Perth-Andover is provided in Appendix A of the Technical Background Report for this Study.

3.2 Beechwood Headpond

3.2.1 Land Use and Building Inventory

To develop appropriate flood protection measures a comprehensive inventory of land use and structures within the flood area was compiled. The inventory was compiled by collating information from existing data (in the form of previous reports and studies) and air photos. This information was then supplemented by:

- field surveys (air and highway);
- input from meetings with local residents; and
- conversations with local officials.

Land use can generally be described as low density development along the River and Trans Canada Highway.

3.2.2 Land Use Control Options

It is recommended that the regulatory measures outlined below be considered to reduce damage caused by flooding in the Beechwood

Headpond Area.

(1) The maximum historic case of the 1987 ice jam flood should be used to define the flood risk zone.

(2) Incentives could be considered for residents within the flood risk zone to help them floodproof existing structures to conform to minimum levels of flood protection. This would eliminate or reduce future flooding compensation expenditures.

(3) Incentives could be considered for residents within the flood risk zone to assist them in relocation if this action is deemed appropriate.

(4) Development could be discouraged within the flood risk zone by making it conditional on the provision of appropriate floodproofing measures.

(5) An official disclosure of flood risk should be provided to any individual transferring, purchasing, or leasing property within the flood risk zone.

It is felt that appropriate land use controls in the flood zone would be achieved effectively by use of Flood Risk Area Guidelines tailored specifically to the flood protection needs of the Study Area.

It is our understanding that NBEPC controls or owns the majority of the land along the riverbank in the headpond area and the only freehold land may be that land within the Village itself. This greatly simplifies the negotiation processes required.

The Flood Risk Area Guidelines should provided Engineering standards, designs and techniques for all development in the flood risk area, and prohibit any development except in accordance with the Guidelines.

The Guidelines may prohibit development that will obstruct or interfere with the normal floodway or free flow of flood waters during a flood period. The Guidelines may require that all development in a flood risk area or in any portion thereof, should be carried out so as not to reduce the flood water storage capacity of such area.

A proposed Flood Risk Area Guideline is provided in Appendix A of the Technical Background Report.

4.0 HYDROTECHNICAL CONSIDERATIONS

The Saint John River Basin is the largest basin in the Province. The River has a total drainage area of 55,143 km^2 (21,300 mi^2), and flows from Southern Quebec and Northern Maine, to the Bay of Fundy. Over half the drainage basin lies within New Brunswick. The mean annual precipitation varies from 900 mm (35.4 inches) at the headwaters to 1200 mm (47.2 inches) at the Bay of Fundy. The river generally experiences two flow peaks; the first occurs during the spring runoff in April to May, and the second occurs during periods of increased rainfall in October and November. The spring peak, which results from a combination of snowmelt and high precipitation, normally leads to the highest peak.

The spring event usually occurs shortly after the breakup of the ice cover on the River. When abnormally high flow occurs early in spring, a mechanical breakup of competent ice cover results. Heavy ice runs and jamming can occur, causing a rapid rise in water levels in the River. This can lead to flooding of land

adjacent to the River and damage to roads, houses, bridges and other structures.

4.1 Local Drainage

The Village of Perth-Andover drainage system includes fourteen (14) culverts which carry flow to the River. The flow from the drainage subbasins leading to the culverts and storm sewers in Perth-Andover is termed the local inflow. If remedial measures were constructed to cut off the connection between the subbasins and the River, the contained local inflow could lead to flooding of the Village independent of the River.
The inverts of these culverts are at elevations very close to the normal summer River level. In the event of high water levels in the River, water would back up through the culverts and contribute to flooding in the Perth-Andover area.

The volume of runoff based on the calculated average runoff is sufficient to cause minor backing up of water if the culverts were blocked by flap gates. The nature of the municipal drainage system in Perth-Andover is such that this would not be of concern for the culverts and storm sewerage outflows from inhabited area of the Village, since the areas drained are small, and the accumulated volumes would be low.

The runoff from the streams with drainage subbasins which extend outside the Perth-Andover area show significant volumes of runoff which could accumulate during a storm event. These basins flow to low lying areas of the Village which are undeveloped and can be used for temporary storage of the water. Approximate storage volume curves were derived (Figure 4-1) for each of these areas using the topography of the Village. The curves were used to estimate the level of water which would result from the

calculated runoff volumes. The water levels which would result from the estimated runoff volumes are shown in Table 4-1.

The estimated depths show that the runoff from storm events during a period when the flap gates are closed would not result in any significant flooding in the Village during average runoff. However, if a major storm such as the 1 in 20 year event, were to occur coincident with a period when the flap gates were closed, there could be some minor flooding in the low lying areas of the Perth side of the River and more significant flooding on the Andover side.

Table 4-1

Water Level Estimates from Local Drainage - under varying flow conditions

FLOW CONDITIONS	Average	Q_2	Q_{20}
LOCATION			
Perth	76.0 m (249.3 ft)	76.4 m (250.7 ft)	77.4 m (253.9 ft)
Andover	76.4 m (250.7 ft)	77.3 m (253.6 ft)	79.1 m (259.5 ft)

Average = average runoff (month of April)

Q_2 = Mean Annual Flow Peak Runoff

Q_{20} = 1 in 20 year Flow Peak Runoff

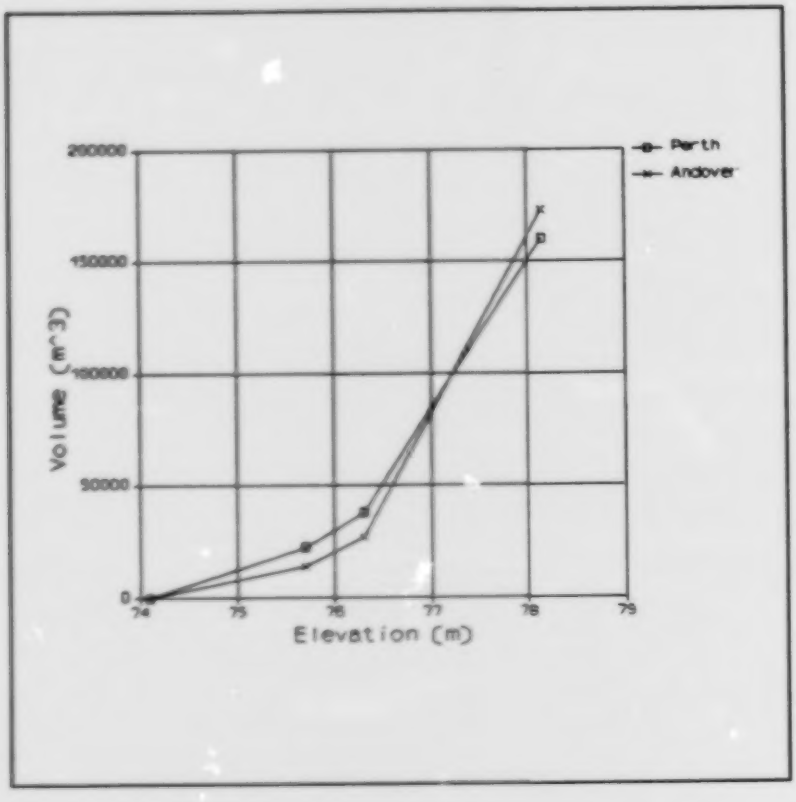


Figure 4-1

Perth-Andover Storage Volume Curves

4.2 Flood Stage Frequency Analysis

The flood frequency is an important component of the assessment of the cost and benefits of remedial measures. It is used to determine the present value of the benefits which would arise from preventing the inundation of an area by flood waters. For rivers subject to flooding due only to high open water, the water level frequency curve, can readily be determined from the flow frequency and water level-discharge curves. Modelling of

the water level profile in the River can be performed to determine the expected water level for the 1 in 20 year and the 1 in 100 year return period open water flood. For the Perth-Andover area, a study was completed to determine these levels (IWD, 1979), resulting in the Flood Risk Map for Perth-Andover.

There are only two ice jam events which is insufficient data to produce an approximate flood water level-frequency curve. These are the ice jam flood of 1976, which resulted in a maximum water level of 78.15 m (256.3 ft), and the ice jam flood of 1987 which greatly exceeded the previous maximum to produce water levels of 79.6 m (261.1 ft) in the Village.

The probability of an ice jam occurring cannot be determined with the current methodologies available anywhere in the world. It is important, however, to approximate a probability (frequency) for the purposes of the economic analysis. *Therefore, for the purposes of this study, it was decided to arbitrarily assign a return period of 100 years to the water level observed during the 1987 event, this is termed the "Base Flood".* A range of return periods between 5 years and 200 years are also examined to determine the sensitivity of the conclusions in the economic analysis to the return period.

The relationship between the 1987 and 1976 breakup flows and an approximation of the normal breakup water level were used to produce an estimate of the return period of lower water levels in the River.

Table 4-2 shows the return periods used in the economic analysis. The Table shows that if a 100 year return period is assumed for the 1987 flood, then the 1976 flood level would be assumed to have a return period of 33 years.

Table 4-2

Water Level Return Periods

Water Level (ft)	Water Level (m)	Return Period (years)					
261.1	79.6	5	10	20	50	100	200
256.6	78.1	3.8	6.7	10	20	33	50
244.4	74.5	2.3	2.3	2.3	2.3	2.3	2.3
						Base Flood	

Although an analysis can be made of the frequency of the riverflow at the time of breakup, this does not provide guidance to whether ice jamming will occur or where it will lodge.

5.0 GEOTECHNICAL ENGINEERING CONSIDERATIONS

5.1 Soil Conditions

The typical soil stratigraphy in the Perth-Andover region can be described as two distinct zones. These zones are generally defined as a surficial deposit which varies from a brown silty sand, to sand, to sandy gravel which then overlies a very thick deposit of coarse sand and gravel. The coefficient of permeability of each of these layers was determined for the purposes of this Study as distinct units.

5.2 Through-ground Flow

The groundwater regime, in general, is influenced by precipitation, infiltration and evaporation. This situation can change when over shorter or longer periods of time, other factors impose a major effect on the groundwater region. One of the common factors which influences the groundwater regime is the presence of natural rivers and lakes. In this case, the variable surface water conditions induced by meterological events are superimposed on the more stable groundwater regime of the river basin. These surface water events may be of such a high intensity (such as a flood), that its impact becomes a short-term, but dominant factor in controlling the groundwater regime.

In the present Study, the available data is inadequate to determine a reasonable value for the range of influence of the through-ground flow. This range is critical for flood damage assessment. The only data which can be used to perform an order of magnitude semi-empirical analysis is the data from piezometers in the vicinity of the Saint John River obtained in April of 1988 (GEMTEC, 1988). These data give the groundwater table readings for changing water levels in the River over a period of 15 hours.

Based on the available data, an assumed range (inland distance) of about 250 m (820 ft) to 300 m (980 ft) from the riverbank was used to investigate the hydraulic interaction. It is the view of Sub Surface Surveys that the actual range may be considerably greater than these assumed values.

The results of the simplified semi-empirical analysis performed indicates that the low lying areas adjacent to the Saint John River will be flooded due to through-ground flow, even if a berm or retaining structure is provided to control the surface (overground) flooding. It must be emphasized that the analysis

is based on many simplifying assumptions and the field data available is insufficient to perform any detailed analyses. The analysis only provides an indication of the nature of the problem in the Village of Perth-Andover and is not corroborated by appropriate field data.

In order to control this flow through pervious soils, a sheet pile wall or a similar cutoff structure would be required. For the benefit-cost analysis, it is necessary to know the depth of penetration into the ground of the sheet piling (embedment) to effectively control the through-ground flow during flooding events. For preliminary estimation purposes, it is recommended that the sheet piles be driven to approximately elevation 70 m (229 ft). For the recommended elevations, sheet pile embedment, on average, would be about 8.5 m (27.9 ft) along the banks of the River. This recommendation would have to be revised when adequate long term data is obtained on the interaction between the River and groundwater table.

Installation of sheet piling to at least elevation 70 m (229 ft) will have a long term permanent effect on the inland groundwater regime in the vicinity of the Saint John River. This aspect is also difficult to quantify at this time with the data available. The consequences of forming an inland basin, must be reviewed in detail prior to the final design and construction.

In order to better understand the rise in groundwater table during high water levels in the River, it is strongly recommended that a monitoring system of wells perpendicular to the river should be installed. The groundwater table and the water level in the River should be monitored simultaneously over a long period of time to obtain statistically significant data. These data are mandatory to obtain a quantified Engineering assessment of the River/groundwater interaction is deemed necessary for future Engineering Works.

5.3 Embankment Stability Guidelines

Sub Surface Surveys has prepared a series of soil parameter guidelines which are suggested to be used in evaluating the slope stability within the Study Area. These parameters are prepared from soil mechanics principles and are presented as an aid to assist non-geotechnical reviewers. The procedures are not intended to replace rigorous Engineering investigations and analyses, rather, they are intended to be a guide for first approximation when more detailed investigations are not available.

These guidelines are based on the Unified Classification System and were developed utilizing chart solutions for slope stability, published empirical relationships and experience.

5.4 Embankment Stability

The slopes in the Study Area are affected by variations in the River and groundwater levels, and it is important to evaluate the effects of these events on the overall slope stability.

These slopes have been analyzed in a generic fashion in an attempt to provide a series of field charts to enable the non-geotechnical Engineer to reasonably assess a slope condition in the field with a reasonable degree of accuracy, but more importantly, with an acceptable assurance that the results will be reproducible between sites and will provide good working guidelines.

The basis for the model developed to construct these generic stability charts is a paper by Bishop and Morgenstern, (1960). The most critical factors to be reviewed in terms of the slope

stability by this generic stability chart method are those of slope angle and pore pressure response.

6.0 BANK EROSION - SAINT JOHN RIVER

An examination of the entire length of the riverbanks within the Study Area was performed. Areas of noted instability as defined by fallen trees, sloughed crest of slopes, or gravel talus failures were defined as potential sources of future instability problems. In addition to the noted unstable areas, areas which had been re-engineered and constructed to achieve stability were also identified as bank erosion sites.

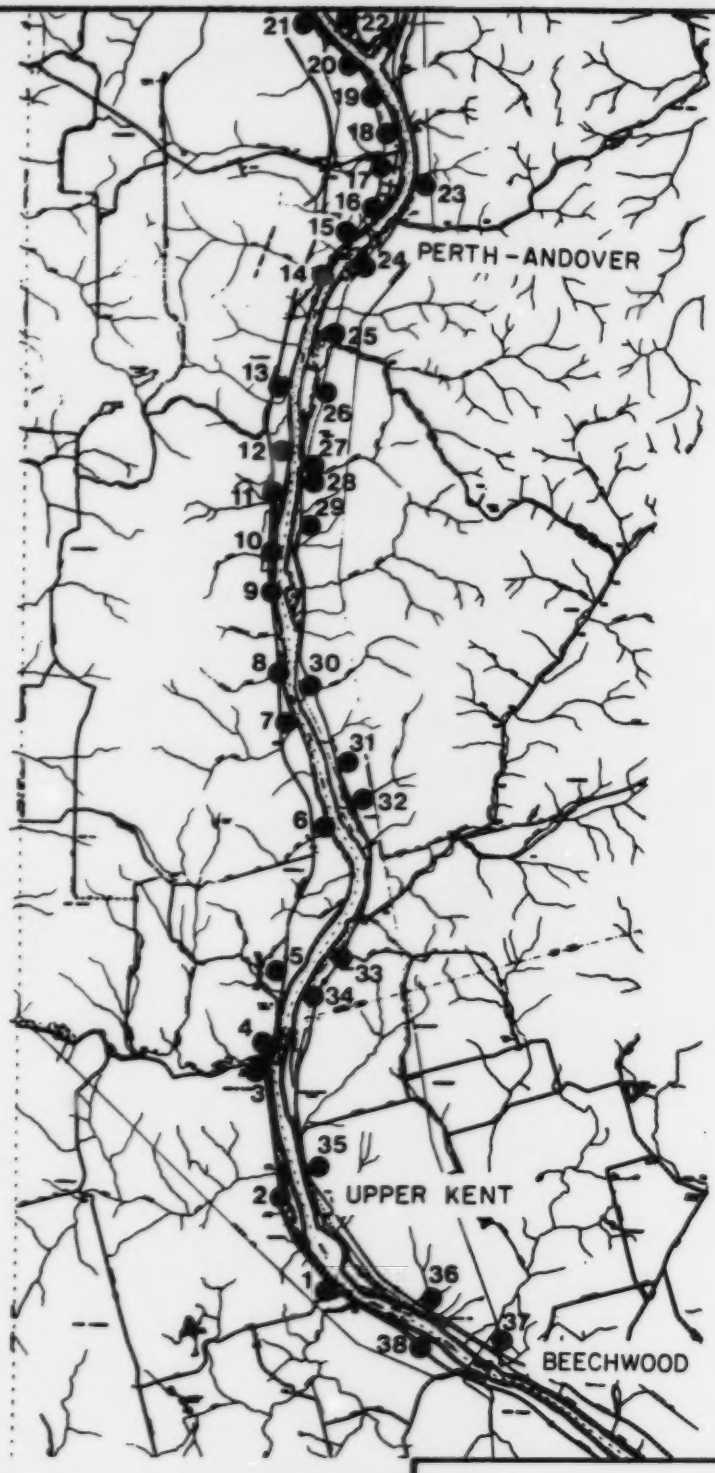
A video tape file of the entire Study Area was compiled and provided to the Working Group under separate cover.

6.1 Sites

A total of thirty-eight (38) sites were identified between the Beechwood Dam and Aroostook Junction. The majority of the identified bank erosion sites were classified as being non critical in nature. Five (5) sites (sites 3, 4, 9, 14, 24) were identified as critical, or in need of immediate action, and one (1) site (site 33) was classified as advisable to undertake action.

Map 6-1 indicates in general terms the position of the sites relative to the small scale mapping of the area.

Erosion at the majority of the sites reviewed was the direct result of natural stream bank movement due to natural forces and was noted in areas where forest or farmland was affected by loss of ground and no structures or public utilities were directly affected.



1 km 0 1 2 3 km

BANK EROSION SITES

SUB SURFACE SURVEYS
CONSULTING ENGINEERS

SCALE: AS SHOWN	DRAWN BY: MA
DRAWING No.: MAP 6-1	DATE: 88 11 15

The critical areas were those sites which would affect structures or access routes or other real property.

The site identification tables in the Technical Background Report present each site in terms of:

- height of the slope, defined as the above water portion.
- the estimated lineal metres of affected area.

6.2 Remedial Costs

The costs associated with remedial action were reviewed based on three (3) general design considerations as follows:

- Regrade the slope to a shallower angle of repose (3 H to 1 V minimum) and thus force improved stability using a cost effective material (ie. locally available pit run gravel). Such slopes however, would still be subjected to normal erosional forces and would have a tendency to steepen at the toe of slope (point of erosion and mass transport) and thus become unstable and deteriorate with time.

- Regrade the slopes to a shallower angle of repose (2 H to 1 V minimum) using a high quality, 300 mm (12 inch) minus, coarse rock fill. This material would be expensive and might only be appropriate for the more critical areas where the benefits of remedial actions would be well defined. This action could be designed to provide a long term stable solution.

- Regrade the existing slopes by reshaping the in situ material to provide a flatter slope aspect to the River. This solution is similar to the first solution with the exception that imported borrow would not be required and therefore

would be very cost effective. This solution again would be subject to deterioration with time, and could not be implemented where water depths in the River exceed 1 m (3.3 ft).

In reviewing the bank erosion sites no costs have been applied to land purchase as it was found that a wide variation in prices predominated, therefore, the estimate of a narrow riverbank acquisition would likely be inaccurate to the point of being misleading.

It is our understanding that the majority of the riverbank property outside the Village limits is either owned or directly controlled by NBEPC and therefore the direct concern is limited to one owner over the majority of the Rivers length.

Costs for remedial action have been prepared in a general format, with the results presented in the Technical Background Report and shown as a cost per lineal metre based on the overall slope height.

7.0 REMEDIAL MEASURES

The high water levels from the 1987 flood produced damage related to both the overland flow of water and to the movement of water through the permeable subsurface layers, which caused basement flooding and foundation damage in areas which may not have been directly damaged by the overland flows. The rapid increase in the groundwater level due to the flood also contributed to the instability of the riverbanks and to slope failures in some places.

The scope of work for this Study requires that methods of mitigating the damage from future flooding up to levels equal to

the 1987 flood be investigated. The remedial measures to be investigated must address the particular problems of the area related to the permeable subsurface layers and to the nature of the flooding. The ice jam type of flood results in an extremely rapid rise in water level, which can reduce the effective time available to take any emergency action in the face of rising flood waters. The 1987 flood waters were reported to rise 2 m (6.6 ft) in barely 5 hours at one point during the flooding.

7.1 Options for Remedial Measures

The identification of remedial measures which will act as effective flood control options, appropriate to the Study Area requires the consideration of a large number of possible measures from which a list of practical measures may be drawn. A number of studies have been done to consider ways of protecting buildings from flooding. These were examined to produce a list of measures to be examined in detail for the Perth-Andover region. The range of potential solutions include using Engineering Works to protect large areas of the floodplain from flooding, as well as floodproofing which is aimed at individual structures. This section considers both types of protection.

The focus of protection from flood damage in the Village, as identified by previous studies, must address three main causes of the damage:

- flooding overland;
- flooding by rising groundwater levels; and
- bank erosion and instability.

The objective of this study is to produce designs for remedial measures only in sufficient detail to allow costs to be estimated. Due to the large number of structures to be protected

and the large area of riverbank to be investigated for stability it is necessary that most of the recommended measures be generic in nature. Thus, they may not address the specific aspects of an individual structure, but may be applicable to a range of similar structures.

Structural remedial measures which will reduce or eliminate the flooding of large sections of the floodplain are termed Engineering Works. These can include dikes which will hold the flood water within the normal riverbanks or flood control structures which can directly control the flow of water in the River and can store or divert water so it does not flood an area. Floodproofing is the reduction or elimination of flood damage to individual properties and is considered applicable on a single structure or property basis. Floodproofing can include the raising of structures or the waterproofing of basements.

Table 7-1 presents the list of remedial measures which are examined. For these measures, conceptual designs are derived in sufficient detail to allow an approximate cost estimate to be obtained. The resulting cost estimates are used in the economic analysis to help determine if the measures are economically feasible as a solution to the problem of flooding in the Study Area.

TABLE 7-1
Selected Alternative Remedial Measures

Structural Measures

- Floodproofing
- Dikes
- Floodwalls
- Raising Roads
- Relocation
- Ice Control Dam
- Channelization
- Bank Stabilization
- Backflow Prevention Valves

Non-Structural Measures

- Floodplain Zoning
- Flood Forecasting
- Land Purchase

7.2 Description of Selected Alternatives

7.2.1 Floodproofing

There are three main categories of floodproofing measures for structures: permanent, contingency and emergency. Permanent measures include raising of buildings and do not require a flood forecast or any action to be taken to be effective. Contingency measures include watertight shields for doors or windows, and require some action prior to flooding and usually a warning to be effectively implemented. Emergency measures may include sandbagging or evacuation and require adequate warning time of the flood as well as a fully operational emergency preparedness plan.

Permanent floodproofing is the most effective method of alleviating flood damage. Typical floodproofing methods are illustrated in Figure 7-1.

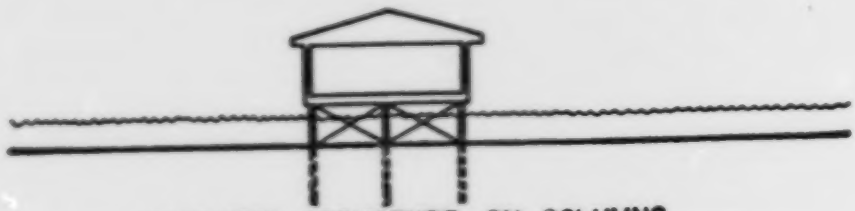
The option of floodproofing can be considered alone or in conjunction with other remedial measures which may offer only partial protection to the area. The level to which the structures must be protected is to be taken as that of the 1987 flood. The flood waters reached a maximum of 2.5 m (8.2 ft) above the first floor elevation in some areas, requiring extensive floodproofing.

Floodproofing for the Study Area considered only the measures which can be applied by retrofitting. This study does not address methods of construction of new buildings which may be built in the floodplain at a later date. It has been assumed that any new structure built in an area affected by flooding will be adequately floodproofed.

Only permanent floodproofing measures which by definition require no action at the time of flooding to be effective were considered. The warning time cannot be assumed to be sufficient to implement contingent measures such as the installation of flood doors or closing flood barriers. The 1987 ice jam flood had a total duration of less than 24 hours, and the water level rose very quickly, at one point rising 2 m (6.6 ft) in 5 hours. Closures and seals are most effective in new construction and require a warning time of 5 to 8 hours to be properly installed (FEMA, 1985).

ELEVATED STRUCTURE ON RAISED FILL

ELEVATED STRUCTURE ON EXTENDED FOUNDATION



ELEVATED STRUCTURE ON COLUMNS

FLOODWALLS AND LEVEES (BERMS)

"WET" FLOODPROOFING

SOURCE: KOZAK, 1987

FLOODPROOFING ALTERNATIVES

SUB SURFACE SURVEYS
CONSULTING ENGINEERS

SCALE: N. T. S.	DRAWN BY: MA
FIGURE No.: 7 - 1	DATE: 88 11 15

7.2.2 Dikes

Dikes have a long record of use for flood control under open water conditions. Required dike elevations can be determined for open water levels with reasonable confidence. Under ice jam flooding conditions, dikes can be used to keep flood waters and ice or both out of a damage prone area. The major difficulty is the determination of the appropriate design level for the ice jam event. Placement of dikes along the riverbanks could eliminate the spreading of the flood waters over the wide area of the floodplain and cause an increase in the flood peak. In the Perth-Andover area this is not expected to be a major problem since this can presently only occur at extremely high water levels and elimination of the over bank area should not have a significant impact on the maximum flood level.

In addition to preventing the inundation of the Village by overland flow, the dike would also prevent the outflow of surface runoff from the Village. The design must consider how to reduce or eliminate the accumulation of seepage and/or internal surface runoff on the dry side of the structure. If adequate space is not available to temporarily store all seepage and runoff that is likely to occur at the site, excess water must be drained to low lying sump areas and pumped to the wet side of the dike. During non-flood situations, surface runoff within the protected area may be discharged through drainage pipes or culverts that extend through the dike. These outlets must be equipped with an automatic check valve to prevent backflow during a flood.

The problem of seepage of groundwater was reviewed and it is apparent from the analysis that a dike will act to hold back the surface water flow while still allowing some through-ground flow to occur. The level of the groundwater surface will be maintained at about the ground surface level, with seepage up to

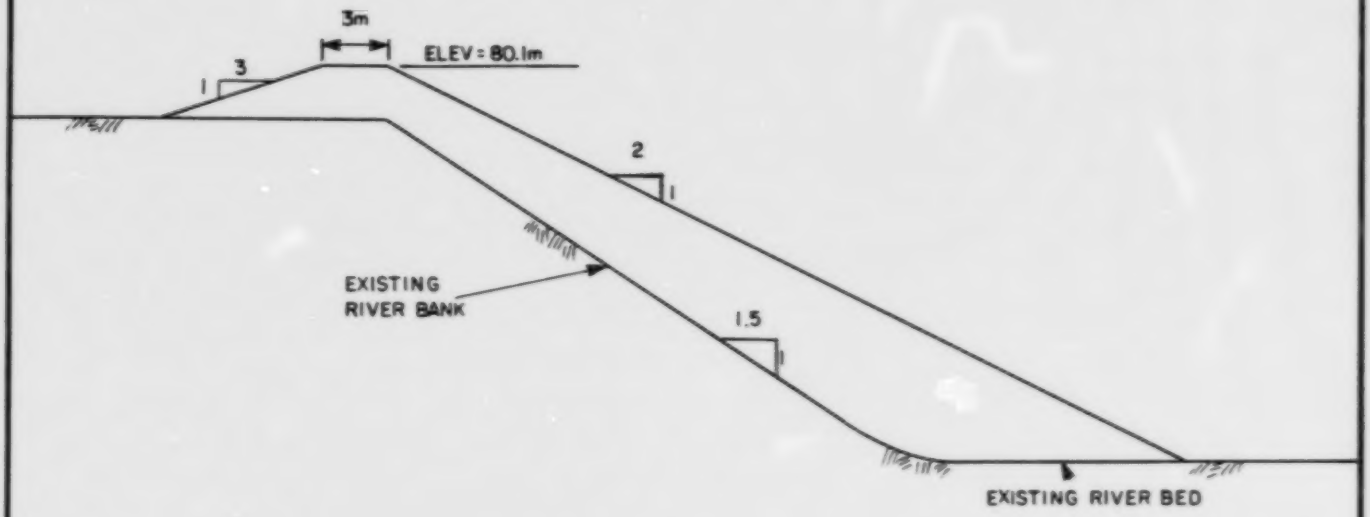
the surface occurring in some low lying areas. The earth dike must therefore be used in combination with floodproofing and reinforcement of basements. Figure 7-2 illustrates a typical dike section.

7.2.3 Raising Roads

The advantage of raising roads is that an existing structure is used, which would be beneficial in areas of limited available land (Figure 7-2). The flooding in the Village of Perth-Andover requires that the road be raised by up to 2.5 m (8.2 ft) in places, although most of the raising would be limited to less than 1.5 m (4.9 ft). This would require ramping of all side roads or driveways entering the main street. In addition, many businesses along the main street have only minimal set back from the road and therefore would lose visibility over the road and require stairways to allow entry to the buildings. This would drastically change the character of the downtown area, especially on the Perth side of the River, and it is expected to meet with opposition from residents.

7.2.4 Floodwalls

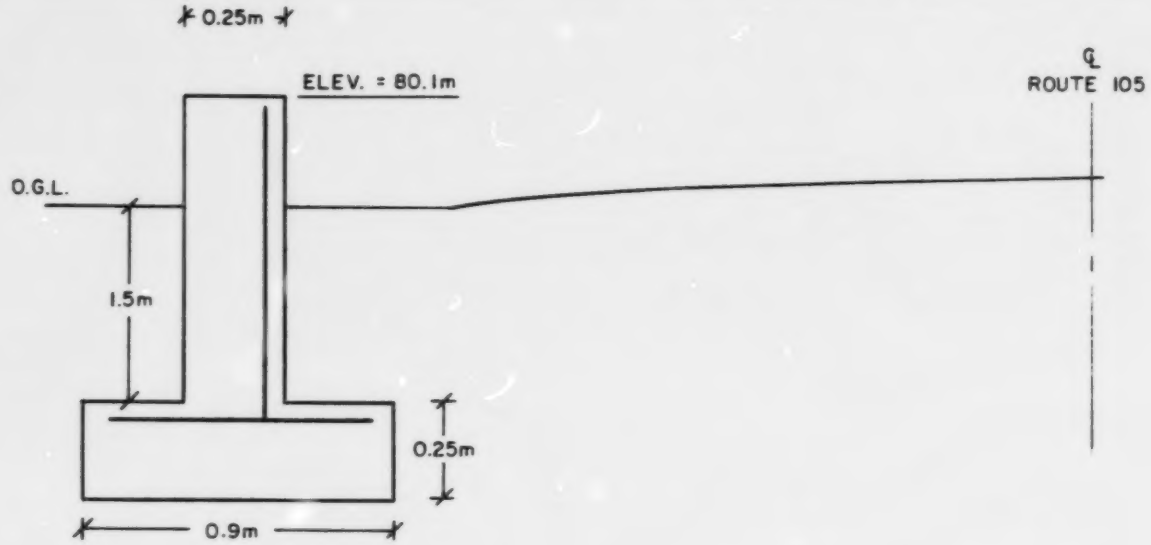
A floodwall is very similar to the dike in function. It prevents overland flow from entering the flood risk area, thereby eliminating the damage from flooding. A floodwall may be a concrete retaining structure or a sheet pile wall. It will generally be much smaller in width than an earth dike, and therefore better suited to the limited space available in Perth-Andover for the construction of flood control measures. The floodwall will cut off the drainage of surface water and will require culverts with backflow prevention valves, similar to the earth dike. Figure 7-3 illustrates some typical floodwall sections.



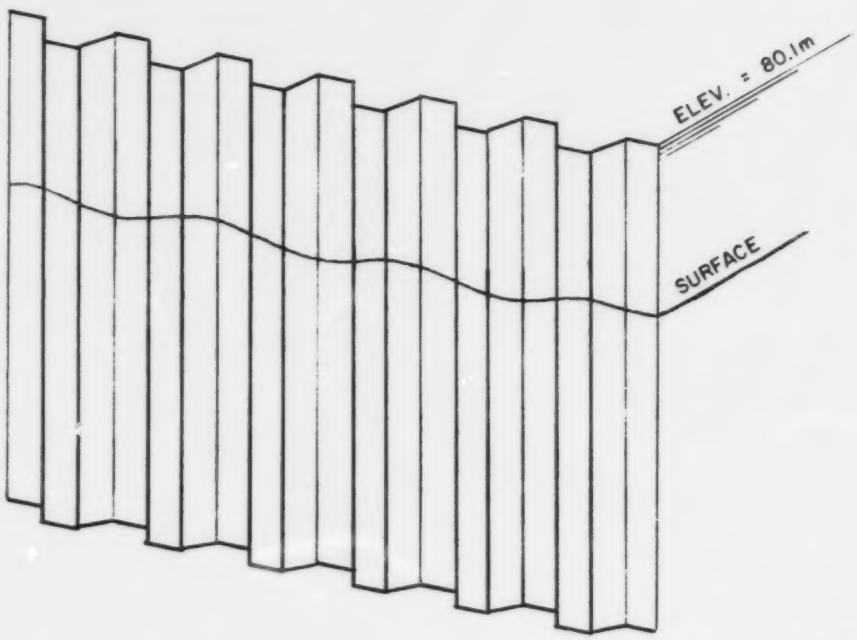
TYPICAL DIKE SECTION

TYPICAL RAISED ROAD SECTION

DIKE AND RAISED ROAD DETAILS	
SUB SURFACE SURVEYS CONSULTING ENGINEERS	
SCALE: N.T.S.	DRAWN BY: MA
FIGURE No. 7-2	DATE: 88 11 15



CONCRETE FLOODWALL



SHEETPILE
FLOODWALL

FLOODWALL DETAILS

SUB SURFACE SURVEYS
CONSULTING ENGINEERS

FIG. No.:	7-3	DRAWN BY:	M.S.
SCALE:	N.T.S.	DATE:	88 11 15

The floodwall will not normally provide a cut off to the through-ground flow and will therefore be subject to the same constraints as the dike for consideration of its effectiveness. The sheet pile floodwall, however, could be driven to an adequate depth to provide a cutoff to the through-ground flow.

A floodwall will cut off the view of the river if it is of sufficient height, and it may not be aesthetically acceptable. The floodwall required in Perth-Andover will reach as much as 2.7 m (8.9 ft) in height on the Perth side of the river, although for most of its length it will average less than 2 m (6.6 ft) high. On the Andover side, the floodwall will not be as high, being less than 1.5 m (4.9 ft) in height for the entire length.

A floodwall was considered for the hospital as an addition to all remedial measures which do not provide full protection from through-ground flow. The hospital has sensitive equipment located at the basement level, necessitating protection of the hospital from both surface and sub surface flow. The protection for the hospital can be provided by a sheetpile floodwall driven to the estimated cutoff depth. The area contained by the floodwall is quite large and will require access for roads. This may be accomplished by the use of flood gates at the road entry points. Ramping over the wall would be a more fail-safe approach in view of the very short warning time available to ensure full sealing of all entry points.

7.2.5 Relocation

A structure which is completely removed from the flood prone area to a location free of flooding will have all possible flood damage eliminated. Some structures are easier to relocate than others, depending on size and style of the house. For large houses, cutting of the structure may be necessary to allow for

transportation on available routes. Very old structures, such as those found in the downtown area may not be strong enough to withstand relocation. Commercial structures may be very difficult to relocate, depending on their function and size. The costs associated with relocation are quite high, and must include the cost of the purchase of a new, serviced lot and the construction of a new foundation, in addition to the costs of removal from the old site and transportation of the structure.

Relocation of houses requires the cooperation of the residents, and can be very unpopular since it will break up neighbourhoods and change access to services and facilities within the local area.

7.2.6 Channelization

Channelization is the modification to the normal River channel through excavation or dredging of the channel. This acts to lower the water levels when an ice jam does occur, since the maximum level of a jam is related to channel flow area. Channelization can also act to reduce the lodgement points and promote the conveyance of ice in the River, preventing the stoppage of an ice run.

The reach from Beechwood dam to Perth-Andover presents a number of known and potential lodgement sites for ice jams. These cannot be reliably identified for channelization, nor can it be ascertained that the improvement of the River at a past lodgement site will be effective in preventing a future ice jam. Therefore, channelization will not be considered as an effective remedial measure for implementation in Perth-Andover.

7.2.7 Floodplain Zoning

Restriction of development in the flood prone areas through the instigation of floodplain zoning legislation can prevent further development in the floodplain. This will cause the loss of some development opportunity, but will prevent some of the increase in the damages associated with flooding.

The costs associated with changes to zoning in a municipality are very difficult to quantify. These costs represent potential loss to future development, and therefore do not compare directly to structural remedial measures suggested for which there is an immediately apparent cost and benefit.

7.2.8 Flood Forecasting

The objective of a flood forecasting program is to predict the rate and magnitude of the discharge and water level rise in a river. A River Forecast Centre has been set up to provide a forecast of the flood events on the Saint John River associated with the open water conditions. Ice jam events cannot be forecast as current technology cannot predict where or when they will occur. The Centre does observe ice conditions and issues warnings to ice jam prone areas.

The difficulty in predicting ice jams means that there must always be a high degree of awareness by the residents of the existing conditions during the time of spring breakup. It will not be possible to issue a warning very much in advance that the water is rising, and the warning will not be able to give the maximum water level to be expected. These conditions are very dependent on the ice volumes present in the River at the time of breakup, the flows, the type and thickness of ice and the location of the jam lodgement. Even if all the details of these

parameters were available, the ice jam limits could still not be predicted with the current knowledge of ice jam formation.

For these reasons it is recommended that local residents continue to provide river observations to the River Forecast Centre. The Centre should continue to issue warnings concerning ice movements. It is important to maintain the public awareness and interest in the area. The 1987 ice jam flood is still very fresh in peoples minds, but the next major flood may not occur for many years and peoples memories of 1987 may tend to fade somewhat if the importance of being alert is not reinforced every spring.

7.2.9 Bank Stabilization

After the flooding of 1987, a number of locations of severe bank erosion were identified, through a joint study by NBDOT and NBEPC personnel, and highlighted for stabilization and repair (NB Power, 1987). The assessment of the benefit-cost ratios of stabilizing riverbanks subject to a natural erosion process is difficult, since the value of land which is being lost can be quite small in comparison to the cost of the remedial works. For aesthetic and safety reasons, stabilization of banks in rural areas, such as the Beechwood Headpond may be advisable. Within a community, erosion and destabilization of riverbanks may pose an immediate threat to a structure, and therefore it would be more beneficial to repair these slopes.

7.2.10 Backflow Prevention Valves

The drainage of municipal runoff in the Village of Perth-Andover is accomplished through a fairly uncomplicated series of culverts and storm sewers which eventually empty into the Saint John River at a total of fouteen (14) outlets along the length of the Village. All of the outlets are well below the flood levels in the River, and some are only barely above the normal summer River levels. Backflow through the lowest of these culverts, into the Bogan area of Perth and at the western end of Andover, provide

the first inlet for flood waters to enter the Village. The simple addition of backflow valves on all culverts could immediately provide protection from overland flow for flood levels in the River up to a maximum of about 77.5 m, the height of the existing banks.

In order to provide complete protection, however, the backflow valves must be used in conjunction with other remedial measures which give full protection from the maximum flood level in the River.

7.2.11 Land Purchase

In some areas it may not be feasible to implement any remedial measure to prevent damage from flooding. The rural areas along the Beechwood Headpond, for example, may only have a small land value, but would require a very expensive structure to provide full protection. In these cases, the land in question could be purchased from the owner so that it will not be of concern, and may be allowed to erode or flood naturally.

It is our understanding that NBEPC controls or owns the majority of the land along the riverbank in the headpond area and the only freehold land may be that land within the Village itself. This greatly simplifies the negotiation processes required.

7.2.12 Ice Control Dam

The flow regime of the River is intersected by hydroelectric power dams at Grand Falls, Tobique and Beechwood. The dams are located on the Saint John River and tributaries, but due to the nature of the River valley, they have very little storage and are therefore generally unable to influence the flooding behaviour of the River.

The present planning by NB Power includes a possible development of the hydroelectric potential between Grand Falls and the Village of Perth-Andover. The dam is being considered as part of an integrated development with an expansion of the Grand Falls development. An appraisal study has recently been completed (Acres, 1988b) as the first phase of a prefeasibility study of this project.

The scope of work for the appraisal study included making an initial assessment of the prospects for ice management using the Morrell project. Acres (1988b) found that the Morrell project can be designed to greatly reduce the potential for flooding due to ice jamming in the Beechwood Headpond and, consequently, can reduce ice flood water levels in the area of Perth-Andover.

Previous studies have pointed out the importance of the volume of ice in an ice jam as a major factor in determining the severity of the upstream flooding (Bethaos, 1984). If local ice and ice from upstream of Grand Falls can be held in the Morrell headpond, then the size of the jams which would be possible would be greatly reduced (Acres 1988b).

The benefit of such a potential ice control structure upstream of the Study Area, would provide positive benefit to the residents in relation to flood control measures. Such a structure has the advantage of not involving Engineering Works within the Village which could change or interfere with the present access to the River.

It is not reasonable to consider benefit-cost relationships for the development with respect to the present study because a hydroelectric project has costs far exceeding those which would be economic solely for ice control ($300 million, 1988 dollars). The Morrell project could provide a long term solution for ice

jam flood damage within the Study Area, however no immediate effects would be obtained with a project completion date projected as 1996 at the earliest (Acres 1988b).

We concur with the conclusions drawn by Acres (1988b) specifically with regards to the requirements for further studies of the ice management capabilities of Morrell to supplement the initial findings. These would allow confirmation of the findings with regard to the reliability of the ice retention capabilities and the associated reduction in water levels in the Study Area.

7.3 Perth-Andover Remedial Measures

The following specific remedial measures are considered for the Study Area:

ALTERNATIVE 1: EARTH DIKE THE ENTIRE LENGTH OF THE VILLAGE, FLOODPROOF ALL BASEMENTS.

ALTERNATIVE 2: CONCRETE FLOODWALL THE ENTIRE LENGTH OF THE VILLAGE, FLOODPROOF ALL BASEMENTS.

ALTERNATIVE 3: SHEETPILE FLOODWALL THE ENTIRE LENGTH OF THE VILLAGE, FLOODPROOF ALL BASEMENTS.

ALTERNATIVE 4: SHEETPILE FLOODWALL THE ENTIRE LENGTH OF THE VILLAGE DRIVEN TO CUTOFF DEPTH.

ALTERNATIVE 5: RAISE ROADS ALONG THE ENTIRE LENGTH OF THE VILLAGE, FLOODPROOF ALL BASEMENTS, AND PROVIDE A PARTIAL FLOODWALL IN PERTH.

ALTERNATIVE 6: RAISE ROADS ALONG THE ENTIRE LENGTH OF THE VILLAGE, FLOODPROOF ALL BASEMENTS, PROVIDE A PARTIAL FLOODWALL IN PERTH AND RAISE ALL STRUCTURES WHICH WERE SUBJECT TO OVERLAND FLOW IN THE 1987 FLOOD.

ALTERNATIVE 7: ELEVATE ALL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING, FLOODPROOF ALL BASEMENTS AFFECTED BY THROUGH-GROUND FLOW.

ALTERNATIVE 8: ELEVATE ALL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING TO A DEPTH OF 1 M OR LESS, OTHER STRUCTURES AFFECTED BY OVERLAND FLOW WOULD BE RELOCATED, FLOODPROOF ALL BASEMENTS AFFECTED BY THROUGH-GROUND FLOW.

ALTERNATIVE 9: ELEVATE ALL COMMERCIAL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING, RELOCATE ALL RESIDENTIAL STRUCTURES AFFECTED BY OVERLAND FLOW, FLOODPROOF ALL BASEMENTS AFFECTED BY THROUGH-GROUND FLOW.

ALTERNATIVE 10: RELOCATE ALL STRUCTURES DIRECTLY AFFECTED BY OVERLAND FLOODING, FLOODPROOF ALL BASEMENTS OF STRUCTURES AFFECTED BY THROUGH-GROUND FLOW.

Maps 7-1 and 7-2 (at the back of the Document) indicate the locations of the various proposed remedial measures specific to the Study Area.

7.4 Basis of Cost Estimate

The cost estimation for the proposed remedial measures has been carried out using 1988 cost figures. The costs for Engineering Works, such as dikes and floodwalls are based on quantity take-offs from conceptual layouts of the remedial measures.

The assessed value of structures in the Study Area was based on information compiled during the Phase I study (Gemtec, 1988). These values were summarized for structures on the Perth and the Andover sides of the Saint John River, and an average value for each obtained. The assessed value was further broken down into residential and non-residential structures for use in the estimates of floodproofing costs. The hospital is not included

in this summary since it is much more expensive than any other structure in Perth-Andover, and will be considered separately in evaluating flood damage reduction measures. The assessed values are summarized in Table 7-2.

Table 7-2
Summary of Average Assessed Values

	Residential	Non-Residential
Perth-Andover	$ 35,583	$ 77,381

The assessed value in Perth-Andover appears to be low, which may reflect the economic nature of the Village and the relative predominance of older structures. The assessed value, however, has been used in this study, in order to provide a basis for comparison as has been done in other evaluations of floodproofing measures (Kozak, 1987, MacLaren, 1978).

Table 7-3 summarizes the cost estimates for each of the remedial measures which were considered for the Village. The table presents the costs with and without the protection of the hospital, however, full protection of the hospital is assumed for the economic analysis.

Table 7-3

Summary of Cost Estimates of Remedial Measures

Remedial Measure	Perth-Andover	With Hospital
1) Earth Dike - plus protect basement	$14,870,000	$16,860,000
2) Floodwall - concrete retaining wall + protect basements	$6,130,000	$8,120,000
3) Floodwall - sheet pile retaining wall + protect basements	$8,300,000	$10,290,000
4) Floodwall - sheet pile retaining wall to cutoff	$16,580,000	$18,570,000
5) Raise Roads - floodwall along houses in Perth + protect basements	$6,010,000	$8,000,000
6) Raise Roads - floodwall in Perth + protect basements + elevate all structures	$6,750,000	$8,740,000
7) Floodproof - elevate all structures affected by overland flow + protect basements	$4,990,000	$6,980,000
8) Floodproof - raise to max of 1 m + relocate + protect basements	$6,070,000	$8,060,000
9) Floodproof - raise commercial buildings only, relocate residents	$7,420,000	$9,410,000
10) Relocate - relocate all structures affected by overland flow + protect basements	$9,170,000	$11,160,000

8.0 ECONOMIC EVALUATION

Significant floods resulting in substantial property damage occurred in Perth-Andover in 1987, 1976, and 1973. Damages in 1987, with $4,742,000 in claims, surpassed previous flood damage claims by a large margin. A total of 167 claims were filed following this last event.

Benefit-cost analysis is a standard economic technique for estimating the net gains to society from a proposed investment. In this Study it is used to rank the ten (10) alternative remedial actions.

Flood frequency was found to have a significant impact on benefit-cost ratios but not on the ranking of the ten (10) alternative remedies under study. The frequency with which the severe 1987 event takes place was varied between 5 and 200 years. These estimated frequencies were used to generate expected annual damage figures for commercial structures. Residential damages were calculated in the same manner, with the Paragon (1985) program allowing as additional inputs the duration of the flooding, warning time, and the velocity of the flood waters. Adjustments were also made for regional differences in consumer prices and property values by calibrating to the damage claims from the 1987 flood.

Some measures, such as dikes or sheetpile floodwalls, would keep out all of the flood waters and result in a 100 percent reduction in damage. Other measures, such as the floodproofing of individual structures, would still permit losses associated with clearing debris and foregone income, estimated at 66% of the flood damage. Commercial structures would also have the additional cost of lost sales during the flooding.

In any benefit-cost analysis one must propose reasonable assumptions upon which to base estimates of future benefits and damages and the assumptions made in this analysis are detailed in the Technical Background Report.

The estimated benefit from each remedial action is the present value of the difference between the expected annual damage without the measure, and the expected annual damage under the remedy.

The benefit-cost ratios for each remedy are given by the present value of the expected benefit stream created by the intervention, relative to the present value of the expected stream of future costs. Since costs are assumed to be incurred in the initial year of the project and subsequent operating and maintenance costs are assumed to be insignificant, the benefit-cost ratios are presented as the present value of the expected benefit over the initial cost outlay.

8.1 Benefit-Cost Ratios - Remedial Measures

Table 8-1 presents the benefit-cost ratios for the ten remedies under consideration. At an interest rate of 10%, only option 4 (the floodwall with the sheet pile retaining wall to cutoff) yields a benefit-cost ratio less than unity. The ranking of the measures by benefit-cost ratios suggest that raising the roads, with a floodwall along houses in Perth (in addition to protecting basements) yields the greatest benefit per dollar in costs (2.12). This is followed by the concrete retaining wall (with basement protection) with a benefit-cost ratio of 2.09, and the floodproofing option where all affected overland flow structures are elevated (with basement protection of others), yielding a benefit-cost ratio 2.05.

Table 8-1
Benefit-Cost Ratios

Measure	i=0.05	i=0.10	i=0.15	Rank
1) Earth Dike	1.85	1.00	0.68	9
2) Floodwall	3.84	2.09	1.40	2
3) Floodwall	3.03	1.65	1.11	6
4) Floodwall	1.68	0.91	0.61	10
5) Raise Roads	3.90	2.12	1.42	1
6) Raise Roads	3.57	1.94	1.30	4
7) Floodproof	3.77	2.05	1.37	3
8) Floodproof	3.26	1.77	1.19	5
9) Floodproof	2.80	1.52	1.02	7
10) Relocate	2.79	1.52	1.02	8

Note: * i = interest rate
* Assumed flood frequency of 1 in 100 years (Base Flood)

8.2 Incremental Benefit-Cost Ratios

Table 8-2 summarizes the benefit-cost ratios in total, and provides information on the incremental benefit-cost ratio, defined as the additional benefits returned by an increment of cost above the last acceptable alternative. The incremental benefit-cost ratio is used to examine the marginal benefit relative to the marginal cost to ensure that benefits rise by more than costs when the next largest project (as measured on a cost basis) is undertaken. If the increase in benefits falls short of the increase in the cost of the remedial project, the remedy under consideration is not as efficient an allocation of societies' resources as was the previously considered remedial action.

TABLE 8-2

Incremental Benefit-Cost Ratios

Measure	Present Value of Expected Benefits	Costs	Incremental Benefit	Incremental Costs	Total B-C Ratio	Incr. B-C Ratio
7	$14,280,000	$6,980,000	$14,280,000	$6,980,000	2.05	2.05
5	$16,940,000	$8,000,000	$2,660,000	$1,020,000	2.12	2.61
8	$14,280,000	$8,060,000	-$2,660,000	$60,000	1.77	-44.33
2	$16,940,000	$8,120,000	$2,660,000	$60,000	2.09	44.33
6	$16,940,000	$8,740,000	$0	$620,000	1.94	0.00
9	$14,280,000	$9,410,000	-$2,660,000	$670,000	1.52	-3.97
3	$16,940,000	$10,290,000	$2,660,000	$880,000	1.65	3.02
10	$16,940,000	$11,160,000	$0	$870,000	1.52	0.00
1	$16,940,000	$16,860,000	$0	$5,700,000	1.00	0.00
4	$16,940,000	$18,570,000	$0	$1,710,000	0.91	0.00

Note: * Remedial measures are listed by increasing cost.
* Applied assumed interest rate i = 10%
* Assumed Flood frequency of 1 in 100 years (Base Flood)

The least expensive remedy is floodproofing (7) at an estimated cost of $6,980,000, with benefits estimated in present value terms at $14,280,000. As compared to doing nothing, floodproofing provides an increase in benefits that exceeds the increase in costs.

The next least expensive project is raising the roads (5) at an estimated cost of $8,000,000, providing benefits of $16,940,000, with complete protection against flood damage. Benefits rise by $2.59 for each additional dollar in costs, suggesting the option of raising the roads is to be preferred to floodproofing (7).

Moving to increasingly more costly remedies will not generate expected benefits, in present value terms, that exceed those of raising the roads. *Hence the incremental benefit-cost analysis points to raising the roads (5) as the most desirable remedy. Note should be made that the intangible costs of this measure may alter this finding.*

8.3 Evaluation

The reported analysis has investigated the relative merits of ten (10) remedial measures aimed at alleviating damages due to flooding in Perth-Andover. Estimates of the potential benefits and costs were identified, and the benefit-cost ratios were examined to determine how robust they were to variation of the discount rate and the flood return period.

The results of benefit-cost analyses based on an interest rate of 10% and a base flood of 1 in 100 year return period are presented in Table 8-3. The estimated cost for the ten proposed remedial measures are also shown.

Table 8-3

Cost Estimates and Benefit-Cost Ratios for Remedial Measures

Remedial Measure	Remedial measures Cost	Benefit-Cost Ratio
5) Raise Roads	$8,000,000	2.12
2) Concrete Floodwall	$8,120,000	2.09
7) Elevate structures affected by overland flow	$6,980,000	2.05
6) Raise Roads and elevate structures	$8,740,000	1.94
8) Elevate to max. of 1 m, relocate others	$8,060,000	1.77
3) Sheetpile Floodwall	$10,290,000	1.65
9) Elevate commercial, relocate residents	$9,410,000	1.52
10) Relocate structures affected by overland flow	$11,160,000	1.52
1) Earth Dike	$16,860,000	1.00
4) Sheetpile Floodwall to cutoff	$18,570,000	0.91

Note: * Cost estimates for remedial measures which protection of hospital
* Remedial measures listed by decreasing benefit-cost ratio
* Interest rate = 10%, base flood of 1 in 100 year return assumed

9.0 CONCLUSIONS AND RECOMMENDATIONS

The Technical Background Report details the methodology used in defining the aspects of the flooding and associated remedial measures that would be appropriate for the Village of Perth-Andover and the Beechwood Headpond area.

The Summary Document presents the synopsis of the findings of the Technical Background Report. It is suggested that the complete documentation be reviewed as additional actions and supporting data are included that may be significant.

PLANNING

1) It is recommended that flood zones be established and controlled by enactment of a By-Law for the Village of Perth-Andover.

2) Incentives should be considered for the existing residents to assist them in either floodproofing or relocating.

3) Development should be discouraged within the defined flood zones.

4) Official disclosure of the flood risk should be made to notify potential developers within the flood risk area.

5) Similar enforcement of development in the unincorporated areas could be undertaken.

HYDROTECHNICAL

6) Culverts have sufficient capacity under backflow conditions to contribute significantly to flooding.

7) It is concluded that culverts should be blocked by flap gates, to protect against the inward flow during flooding.

GEOTECHNICAL

8) It was concluded that the flood water movement in the Village by through-ground flow could be a significant factor in the flooding.

9) It is recommended that a study should be undertaken to define the response of the groundwater table to the rise in the River water level.

10) Thirty-eight (38) sites of riverbank erosion were identified and it was concluded that five (5) sites are in need of immediate action.

11) Remedial measures recommended for slope stabilization are presented in the document.

REMEDIAL MEASURES

12) Further study of the ice management capabilities of the proposed Morrell Hydroelectric Development should be undertaken. The development should be encouraged as a potential long term solution to the problem of ice jam flooding at Perth-Andover.

13) A number of potential remedial measures for flood protection were reviewed from which ten (10) selected measures are recommended and were analyzed in detail.

14) It is recommended that the hospital be protected from overland and through-ground flows. This protection is recommended regardless of other remedial actions selected.

ECONOMICS

15) The selected remedial measures are presented in Table 9-1 with the associated costs and the ranking based on the benefit-cost ratios developed.

Table 9-1
Cost Estimates and Benefit-Cost Ratios for Remedial Measures

Remedial Measure	Remedial measures Cost	Benefit-Cost Ratio
5) Raise Roads	$8,000,000	2.12
2) Concrete Floodwall	$8,120,000	2.09
7) Elevate structures affected by overland flow	$6,980,000	2.05
6) Raise Roads and elevate structures	$8,740,000	1.94
8) Elevate to max. of 1 m, relocate others	$8,060,000	1.77
3) Sheetpile Floodwall	$10,290,000	1.65
9) Elevate commercial, relocate residents	$9,410,000	1.52
10) Relocate structures affected by overland flow	$11,160,000	1.52
1) Earth Dike	$16,860,000	1.00
4) Sheetpile floodwall to cutoff	$18,570,000	0.91

Note: * Cost estimates for remedial measures includes protection of hospital (conclusion item 14).
* Remedial measures listed by decreasing benefit-cost ratio.
* Interest rate = 10%, base flood of 100 year return assumed.

16) It is concluded that:

- Maximizing the dollar value of benefits per dollar spent leads to the selection of the remedial measure of raising roads, as does the maximizing the net present value of the remedial project.

- An examination of the additional benefits due to an additional cost increment leads to the selection of the remedial measure of raising the roads.

- If raising the roads is excluded on the grounds it carries negative externalities, the most efficient remedial measure becomes the concrete floodwall.

- The ranking of measures is insensitive to the choices of the discount rate and the flood return period.

- The construction of the remedial measure will have positive effects on employment and incomes in the Province.

17) Non-economic issues such as aesthetics, social, cultural and planning considerations may alter the ranking of the remedial measures which have been assessed from a solely economic perspective.

10.0 REFERENCES

Acres International Limited, January 1988[a]. 1987 SAINT JOHN RIVER FLOODING for the New Brunswick Electric Power Commission.

Acres International Limited, August 1988[b]. GRAND FALLS-MORRELL INTEGRATED DEVELOPMENT. Project Appraisal for the New Brunswick Electric Power Commission.

Acres International Limited, September 1976. SAINT JOHN RIVER ANALYSIS OF 1976 ICE JAMS for the New Brunswick Electric Power Commission.

Beltaos, S., 1984. LECTURE NOTES ON ICE JAMS. From the Workshop on Hydraulics of River Ice, NRCC Subcommittee on Hydraulics of Ice Covered Rivers, Fredericton, New Brunswick.

Bishop,A.W. and Morgenstern,N., STABILITY COEFFICIENTS FOR EARTH SLOPES, Geotechnique, Volume X, Number 4, December 1960.

FEMA, 1985, Federal Emergency Management Agency (1985) FLOOD PROOFING NON-RESIDENTIAL STRUCTURES. Washington, D.C., U.S. Government Printing Office.

GEMTEC, June 1988. ICE JAM FLOOD STUDY, PERTH-ANDOVER & SIMONDS, PHASE I, Field Surveys Geotechnical and Hydrogeological Investigations, Fredericton, N.B.

Inland Waters Directorate, December 1979. HYDROTECHNICAL STUDY OF THE BEECHWOOD HEADPOND, Water Planning and Management Branch, Atlantic Region, Halifax, Nova Scotia.

Inland Waters Directorate, 1974. NEW BRUNSWICK FLOOD, APRIL-MAY 1973, Technical Bulletin No. 81, Environment Canada, Halifax, Nova Scotia.

James F. MacLaren Limited, March 1978. FLOOD PROOFING - A COMPONENT OF FLOOD DAMAGE REDUCTION, for Department of Fisheries and Environment Canada.

Kozak, V. November 1987. RESIDENTIAL GUIDELINES FOR FLOODPLAIN CONSTRUCTION, Stephens Kozak Architects Ltd. prepared for Innovative Housing Granite Program, Alberta Municipal Affairs.

New Brunswick Electric Power Commission, 1987. ASSESSMENT OF (CRUCIAL) BANK EROSIONS OF SAINT JOHN RIVER - BEECHWOOD HEADPOND - APRIL 1987 FLOOD. pp.39

Paragon Engineering Ltd., 1985. DEVELOPMENT OF FLOOD DEPTH-DAMAGE CURVES FOR RESIDENTIAL HOMES IN ONTARIO, VOLUMES 1 AND 2, Prepared for the Canada-Ontario Flood Damage Reduction Program, Toronto, Ontario.

U.S. Department of Housing and Urban Development. October, 1976. NATIONAL FLOOD INSURANCE PROGRAM. Federal Register, Vol 41, No. 27, October 26, Revision to Federal Insurance Administration. Pp. 46962-46992.

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